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Progress Report

CLUBMOSS (*Selaginella densa*) RESEARCH

Montana Agricultural Experiment Station

and

Bureau of Land Management
United States Department of the Interior

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General Report

This report includes activities primarily from July 1, 1966 to June 30, 1967, although some data from earlier work are included.

Personnel for this project during the last year included:

Dr. G. F. Payne, Coordinator

Mr. J. E. Taylor, in charge of investigations in the Department of Animal and Range Sciences.

Mr. L. O. Baker, in charge of investigations in the Department of Plant and Soil Sciences.

Mr. H. A. R. Houlton, in charge of soil and moisture investigations at North Montana Branch Station.

Appreciation is expressed to the following for contributions of many kinds to this project during the last year:

a. Bureau of Land Management:

Mr. Nyles Humphrey, District Manager, Malta and members of his staff.

b. North Montana Branch Station:

Mr. Claude Windecker, Superintendent.

c. Montana State University, Bozeman:

Dr. A. R. Southard, Department of Plant and Soil Science.

Dr. D. E. Ryerson, Extension Range Scientist.

d. Board of Directors, Buggy Creek State Grazing District, Glasgow.

Because of the close relationship of this project and the mechanical renovation studies supported by State and Federal Funds at North Montana Branch Station, Havre, the results of the Havre studies as they affect knowledge about the management of clubmoss-infested ranges are included in this report.

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HIGHLIGHTS

Mechanical phase:

The optimum post-treatment deferment period for mechanically renovated clubmoss ranges appears to be two growing seasons.

Post-treatment deferment is essential for such ranges because of the high degree of preference shown by cattle for treated areas. Similarly, mechanical treatments probably should be fenced separately from untreated range areas to reduce management problems.

Forage production increases following mechanical renovation have ranged from 50 to 300 percent. These increases continue at least three years following treatment. Further observation may show longer effects.

Differential responses between renovated and untreated areas are greatest on below-normal moisture years.

The effectiveness of mechanical treatments increases with treatment width, with an optimum level of about 20-22 inches. This allows maximum forage response while minimizing weed invasion.

While clubmoss has not reinvaded scalped strips, several other species are invading these denuded areas. The primary species of concern is fringed sagewort, which has become a serious problem at every location.

The BLM chisel plowing study south of Malta (nichols Coulee RCA) is producing some forage yield increases, but further observation is necessary.

Larger scale mechanical treatments have been established for grazing studies. These will provide information on cost-return relationships, animal responses, and vegetational responses under various kinds of grazing management.

Soils phase:

The protein content of native grasses when growing in pitted and interseeded range is increased. The protein increase ranges from 2 to 2.5 percent and is highest in the grasses closest to the inverted sods of pitting and interseeding.

Increased soil nitrogen production under the inverted sod is responsible in part for the increased protein content and production of the native forage with pitting and interseeding techniques. The increase in soil nitrogen production per acre is small, 9.6 pounds, but is significantly important to increased production.

The increased protein content of the native grasses does not carry through into the fall period. While the increased production remains, the protein content of grass on treated and untreated range drops sharply to about four percent.

Soil moisture storage under areas of pitting and interseeding is increased. The increase in soil moisture storage to three feet of depth under a treated area can be one acre inch. The greatest soil moisture storage increase is under the sods and can be as high as 1.38 inches. Increased soil moisture coupled with increased soil nitrogen production accounts for increased production.

Soil surface temperatures do not appear to have any influence upon soil moisture use from either treated or untreated areas of clubmoss range.

Chemical phase:

Ammate, atrazine, and monuron have given best control of clubmoss with least injury to desirable grasses, sedges and forbs from both spring and fall treatments. Atrazine and monuron encourage the deep rooted plants. Ammate stimulates production of all grasses.

There is no evidence that the addition of a 50 pound per acre nitrogen application increased herbicicde effectiveness.

Inconclusive results were obtained with the addition of surfactants to enhance the effectiveness of ammate and monuron. Additional tests are suggested.

DEPARTMENT OF ANIMAL AND RANGE SCIENCES

Montana Agricultural Experiment Station

July 1967

Introduction:

The research reported here was accomplished at three study locations: North Montana Branch Station (Havre), Buggy Creek State Grazing District (Glasgow), and Nichols' Coulee Resource Conservation Area (Malta). Because of basic differences in approaches and responses among locations these studies will be discussed individually and then a generalized summary made.

North Montana Branch Station, Havre

This research was primarily concerned with continued evaluations of range interseeding and pitting treatments which had been made in 1963 and 1964. Production and species composition changes under protection and under cattle grazing are being followed through a series of years to study:

a. the optimum post-treatment deferment periods to maximize favorable treatment responses,

b. livestock grazing patterns related to range renovation treatments,

c. the longevity of range renovation treatments under livestock grazing and deferment.

Previously protected areas of pitting and interseeding were grazed during both spring and fall, 1966. Other tested areas previously grazed were grazed again, so that there were areas representing several different post-treatment deferment periods. This study will continue one more year and then be analyzed for differences among years, seasons and deferment periods. Preliminary observations suggest that two growing seasons' deferment may be best for both pitting and interseeding. Cattle show a definite preference for both pitted and interseeded range. Total forage production from mechanical treatments had increased 50 to 300 per cent, depending upon species composition and original clubmoss density.

In another part of this project an area which had received various plowing and manuring treatments during the period 1925-1934 was re-examined for evidence of clubmoss responses. On this ungrazed site visual differences in clubmoss density persisted after 30 to 40 years following treatments[1/].

Buggy Creek State Grazing District, Glasgow

Stand establishment data were collected from range interseeding trials. Even though growing season precipitation was about 20 per cent below normal, substantial production increases were realized (Table 1). Most of these increases came from stimulation of the pre-existing cover, especially thickspike and western wheatgrasses (Table 2). The seeded species contributed little weight. Best yields of seeded species came from slender wheatgrass,

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[1/] Dolan, John Joseph. 1966. Long-term responses of dense clubmoss (Selaginella densa Rydb.) to range renovation practices in northern Montana. M. S. Thesis, Montana State University, Bozeman. x ≁ 83 pp.

Table 1. Vegetational production, pounds per acre, 1966. Range interseeding - Glasgow

Species	1[1]	2	3	4	5	6	7	8	9	10
Seeded species	2	30	10	54	1	--	30	84	35	28
Residual vegetation										
Wheatgrasses	374	243	300	331	398	281	359	354	184	318
Needle-and-thread	86	63	28	20	100	22	16	8	108	51
Green needlegrass	--	1	109	33	--	--	--	3	--	16
Miscellaneous grasses[2]	287	212	273	256	242	238	228	384	222	264
Perennial grasses + sedges	751	555	722	804	744	541	639	838	562	693
Forbs	115	118	317	135	119	166	163	84	369	178
Fringed sagewort	65	55	158	47	113	99	48	10	79	76
All forbs & shrubs	180	172	476	182	232	265	211	94	448	254

[1] 1 Mandan ricegrass
2 Grass mix
3 Green needlegrass
4 Thickspike wheatgrass
5 Basin wildrye
6 Sainfoin
7 Bluebunch wheatgrass
8 Slender wheatgrass
9 Western wheatgrass
10 Species average

[2] Includes:
Sandberg bluegrass, prairie junegrass, plains reedgrass, speargrass.

Table 2. Percent composition by weight, 1966. Range interseeding, Glasgow

		SPECIES TREATMENT PLOTS									
	1[1/]	2	3	4	5	6	7	8	9	10	11
	%	%	%	%	%	%	%	%	%	%	%
Seeded species	0.21	4.06	0.85	5.49	0.12	0.00	3.54	8.96	3.51	2.92	--
Residual vegetation											
Wheatgrasses	40.17	33.47	25.05	33.62	40.72	34.84	42.18	37.90	18.19	33.54	21.25
Needle-and-thread	9.29	8.69	2.34	2.02	10.20	2.67	1.89	0.87	10.75	5.36	24.97
Green needlegrass	0.00	0.14	9.10	3.34	0.00	0.00	0.00	0.30	0.00	1.73	0.00
Misc. grasses [2/]	30.80	29.19	22.77	26.02	24.77	29.57	26.81	41.19	21.94	27.83	32.31
Perennial grasses + sedges	80.63	76.31	60.29	81.56	76.23	67.13	75.18	89.88	55.62	73.14	78.53
Forbs	12.36	16.17	26.48	13.70	12.24	20.58	19.20	9.01	36.54	18.85	16.60
Fringed sagewort	7.01	7.52	13.23	4.74	11.53	12.29	5.62	1.11	7.84	8.01	4.87
All forbs & shrubs	19.37	23.69	39.71	18.44	23.77	32.87	24.82	10.12	44.38	26.86	21.47

[1/]
1 Mandan ricegrass
2 Grass mix
3 Green needlegrass
4 Thickspike wheatgrass
5 Basin wildrye
6 Sainfoin
7 Bluebunch wheatgrass
8 Slender wheatgrass
9 Western wheatgrass
10 All species
11 Check

[2/] Includes: Sandberg bluegrass, prairie junegrass, plains reedgrass, speargrass

thickspike wheatgrass, and western wheatgrass. Sainfoin, basin wildrye, and Mandan ricegrass were the least productive.

Table 3 compares interseeding pitting, chisel plowing and untreated range. Interseeding continues to produce higher yields than the other mechanical treatments. This is felt to be due to the relatively greater disturbance of the clubmoss sods and the overturning of these sods in interseeding. Fringed sagewort is most common on the chisel plowing, although it is increaseing on the other treatments.

Table 3. Vegetational production from interseeding, pitting and chiseling, 1966. Glasgow.

Species	Interseeding	Pitting	Chiseling	Untreated
	- - - - POUNDS PER ACRE - - - - - - - - -			
Seeded species	28	--	--	--
Residual vegetation				
Wheatgrasses	318	103	242	107
Needle-and-thread	51	76	89	126
Green Needlegrass	16	--	--	--
Miscellaneous grasses	264	313	195	162
Perennial grasses + sedges	693	493	526	395
Forbs	178	100	158	84
Fringed sagewort	76	99	226	24
Forbs & shrubs	254	199	384	108
Total vegetation	947	692	910	503

These treatments were all grazed by cattle during late autumn on 1966. Controlled moderate grazing will be allowed annually and vegetational responses followed.

Some of the local ranchers cooperated in the establishment of a new pasture-size interseeding and pitting study in autumn, 1966. This study, located on the Cornwell ranch, will be subjected to grazing management treatments and will be incorporated into the present research project.

Chisel Plowing Study - Nichols' Coulee RCA

This study was established by personnel of the Malta District Office, Bureau of Land Management, in the autumn of 1964. Four intensities of chisel plowing were applied to 700 acres of grassland. The treatments were:

2,4,4"	Three times through: first with two-inch chisels at two inches depth, then at right angles at four inches, then with ten inch sweeps at 45 degree angle to the first treatments.
2"	Once through with two-inch chisels at two inches depth.
2,4"	Twice through with two-inch chisels; the first time at two inches depth and then at right angles at four inches depth.
4"	Once through with two-inch chisels at four inches depth.
Checks	Two untreated areas were left adjacent to treatment blocks to serve as controls.

This study was evaluated by Montana Agricultural Experiment Station personnel during the summer of 1966. Production data (Table 4) were collected from deferred areas of all treatments except the 2" treatment, where a grazing exclosure was not provided.

Table 4. Vegetational production, 1966, Malta chisel plowing.

	Treatments				
	Check 1	2,4,4"	Check 2	2,4"	4"
Species	- - - - - - -	- -	pounds per acre	- -	- - - - - - -
Wheatgrasses	182	227	70	149	82
Other grasses and grasslike plants	79	64	52	121	84
All forbs	3	60	2	2	1
Fringed sagewort	0	76	97	112	83
All half-shrubs and shrubs	1	1	91	9	4
TOTAL VEGETATION	265	428	312	393	254

Comparisons among treatments are marked by differences in soil characteristics. This is evident in the two check plots. Check plot #1 is adjacent to treatment 2,4,4", while Check #2 is located between treatments 4" and 2,4". Recognizing these differences, it appears that chisel plowing at the maximum concentration (2,4,4") increased yields of wheatgrasses, forbs, and fringed sagewort. The latter two groups are generally undesirable from a livestock grazing standpoint but useful to some degree to wildlife. This treatment should be evaluated at least one more year before any conclusions are reached regarding its effectiveness. The lesser intensities of chisel plowing showed less marked production changes. The 2,4" treatment appears to increase grass production but the 4" treatment does not.

It was noted that some of the area included in the chisel plowing study consisted of relatively small islands of relict developed soils in a matrix of erosion pavement. Mechanical disturbances of such sites creates conditions favorable for wind erosion. This may explain some of the seemingly erratic responses.

The lack of replications, the omission of grazing exclosures from the 2" treatment and the confounding of location and treatment due to the distance between treatments prevent statistical analyses of the data. It would have been desirable to have established utilization studies outside the exclosures so that the effects of grazing could be evaluated.

This area will be studied again in 1967, and the photographic plots established in 1966 will be re-taken.

Summary

Wide scale mechanical treatments have been established in clubmoss ranges in northern Montana. Species changes, production increases, and cattle use patterns suggest that interseeding probably produces the greatest forage increases on the widest variety of sites.

DEPARTMENT OF PLANT AND SOIL SCIENCES

Montana Agricultural Experiment Station

July 1967

Introduction

Field studies for chemical control of clubmoss began at Havre and Norris in the spring of 1964. A third location, Glasgow, was added in the fall of 1964. Since that time additional tests involving the more promising treatments have been made at all locations. Since the first application date the treatments have been evauluated visually for clubmoss control and by clipping all vegetation except clubmoss at ground level. The clipped plants are separated according to species or groups of species. Samples are then dried and weighed to the nearest hundreth of a gram. Results are being statistically analyzed using the services available at the M.S.U. computer laboratory.

During 1966 all of the previously treated plots were evaluated either visually or by clipping, or both, and several new plots were established using a single rate of four of the most promising herbicides determined in the earlier research. These treatments were applied in late March to randomized, triplicated plots 40 x 60 feet in size at Norris and Havre. Nitrogen fertilizer was applied to half of each plot at the rate of 50 pounds of N per acre using a paired plot design. The treatments included ammate 10 lbs, atrazine 2 lbs, monuron 2 lbs, paraquat .5 lb plus surfactant, and an untreated check.

Treatments were made with a knapsack sprayer equipped for constant air pressure and using an 8 foot boom. Chemicals were applied in a volume of water equal to 40 gallons per acre.

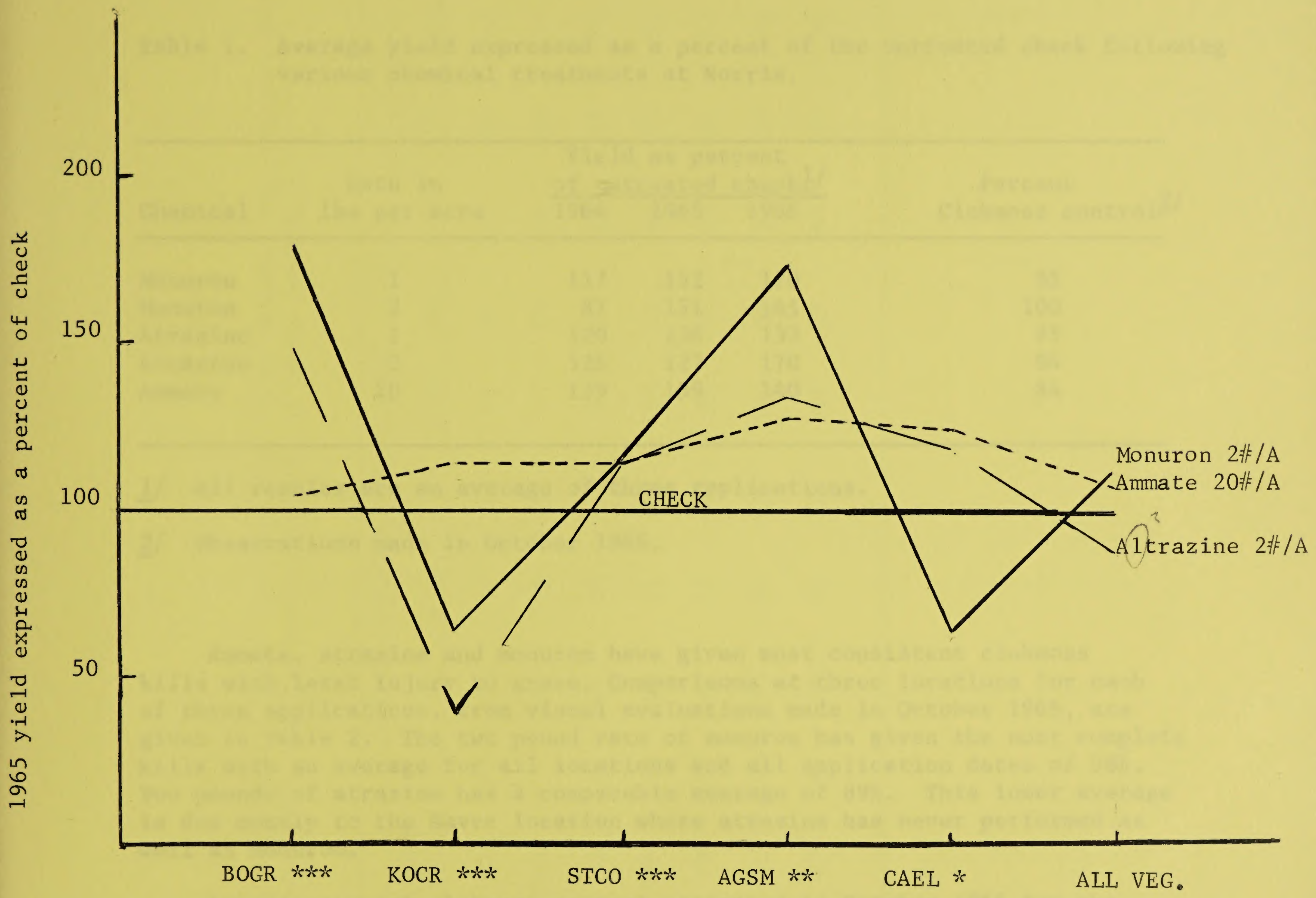
In addition ammate, monuron, atrazine and paraquat were applied at various rates in late June, 1966 at Norris to triplicated plots 8¼ x 16½ feet in size. Dupont spreader sticker was used with ammate and monuron at a rate equal to .5% by volume of the water carrier. Paraquat was used with X-77 surfactant, also at .5% by volume of carrier.

Results and Discussion

The effect of clubmoss on yield of other vegetation has been demonstrated repeatedly. Where the clubmoss is controlled early in the growing season without grass injury increased yields occur that same season. When grass injury results from the use of a particular herbicide the increase may be dependent on recovery of the grass. Such trends are illustrated by the average results from Norris using yield data for each of the last three years from plots treated in early spring 1964 (Table 1).

Percentage composition of the grasses present on the experimental site may change with chemical application. Certain grass species react differently to different chemicals. Such results can be seen in Figure 1 where average yield data from two treatment dates at one to three separate locations are presented in graph form for three chemical treatments. *Bouteloua gracilis* and *Agropyron smithii* show a considerable increase while *Koeleria cristata* and *Carex eleocharis* show a decrease in yield due to

Figure 1. Average 1966 yield of vegetation, expressed in percentages of untreated range, from areas treated in the autumn of 1964 and the spring of 1965.



* Data from one location
** Average of two locations
*** Average of three locations

Bogr = Bouteloua gracilis
Kocr = Koeleria cristata
Stco = Stipa comata
Agsm = Agropyron smithii
Cael = Carex eleocharis

monuron and atrazine treatments. Generally the shallow rooted species were injured more. Differences due to the use of ammate were smaller and less variable.

Table 1. Average yield expressed as a percent of the untreated check following various chemical treatments at Norris.

Chemical	Rate in lbs per acre	Yield as percent of untreated check[1/] 1964	1965	1966	Percent Clubmoss control[2/]
Monuron	1	117	152	170	95
Monuron	2	87	151	165	100
Atrazine	1	120	136	133	95
Atrazine	2	126	127	170	94
Ammate	20	139	159	140	84

1/ All results are an average of three replications.

2/ Observations made in October 1966.

Ammate, atrazine and monuron have given most consistent clubmoss kills with least injury to grass. Comparisons at three locations for each of three applications, from visual evaluations made in October 1966, are given in Table 2. The two pound rate of monuron has given the most complete kills with an average for all locations and all application dates of 98%. Two pounds of atrazine has a comparable average of 89%. This lower average is due mostly to the Havre location where atrazine has never performed as well as monuron.

Average percent clubmoss control estimated in October 1966 for the large plots treated in early 1966 are given in Table 3. Results were generally good except for paraquat which was only partially satisfactory for clubmoss control and also caused more injury to the grasses.

There is no evidence that a 50 lb per acre application of nitrogen increased clubmoss kills.

The use of surfactants with some herbicides increases their effectiveness. Paraquat has been used with X-77 with variable results. DuPont Chemical Company suggested that the effectiveness of both ammate and monuron against clubmoss could be increased with the addition of their spreader

Table 2. Average visual percent clubmoss control (October 1966) from chemical applications made in the fall of 1964 and 1965, and the spring of 1965, at three locations.

Treatment Chemical	Rate in lbs/A	Percent clubmoss controlled[1]												Final Av.
		Glasgow				Havre				Norris				
		F'64	S'65	F'65	Av.	F'64	S'65	F'65	Av.	F'64	S'65	F'65	Av.	
Ammate	10	30	92	83	68	33	63	95	64	12	93	87	64	65
Ammate	20	68	100		84	78	100		89	22	90		56	76
Atrazine	1	35	33	53	40	10	17	55	27	72	87	94	88	52
Atrazine	2	100	100	93	98	65	97	58	73	94	94	96	95	89
Monuron	1	42	73	75	63	37	68	84	63	97	33	93	74	67
Monuron	2	100	100	100	100	88	100	100	96	99	99	98	99	98
Average --		62	83	81	76	52	74	65	69	66	83	78	79	

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[1] Average of three replications

sticker. A test to study such a conclusion was made June 23, 1966 at the experimental site at Norris (Table 4). Percent clubmoss kill as estimated in June 1967 were more complete from the ammate and monuron applications than from any test made previously at comparable rates. The results are not conclusive and suggest the need for further evaluation of herbicide - surfactant combinations and possibly for additional summer treatments.

Table 3. Estimated percent clubmoss control from plots treated at Norris and Havre in April 1966[1/].

	Rate in lbs/acre	Havre Oct. '66	Norris Nov. '66
Ammate	10	77	60
Atrazine	2	67	98
Monuron	2	97	98
Paraquat + Surfactant (.5% x-77)	.5	45	50

[1/] Average of three replications from observations made in October 1966.

Table 4. Average estimated percent clubmoss control from herbicide - surfactant tests made June 23, 1966 at Norris[1/].

Chemical	Rate in lbs/A	Percent clubmoss control
Ammate	5 + surfactant	88
	7.5 + "	100
	10 + "	100
	10 + "	100
Monuron	1 + surfactant	97
	2 + "	100
	2	100
Paraquat	1/4 + x-77	22
	1/2 + "	40
	3/4 + "	40
	3/4 + "	53
Check		0

[1/] Average of three replications.

NORTH MONTANA BRANCH STATION

Montana Agricultural Experiment Station

July 1967

Introduction:

The soil phase of the clubmoss project was mainly concerned with evaluation of the nitrogen nutrition factor of native grasses on pitted clubmoss ranges and the relationship of temperature and moisture on pitted range.

Leachate studies, utilizing isolated inplace soil blocks were initiated. Soil blocks of 18" x 18" x 12" were laminated with cheesecloth and parafin wax, however, the technique was not adaptable to field study and had to be abandoned.

The same technique was employed with an essentially similar greenhouse study; but the problem of keeping good contact between the lamination and the soil in order to leach all the nitrate nitrogen from a given volume of soil for a given volume of water, was not solved. Use of plastic materials for lamination of inplace soil blocks was investigated but no reportable data have been collected to date.

Artificial application of water to mechanically treated areas was done and hourly soil temperatures measured and soil moisture content measured every three hours for 48 hour periods. No correlation was found between temperature and moisture movement but more definite information on moisture storage was obtained.

Protein Content of Native Grasses--Slate Cover and Hand Pitting.

Protein was determined on grass samples clipped from six treatments of the original pilot study, which were varying concentrations of slate cover and 25 percent hand pitting with and without sods (Table 1).

Table 1. Percent protein of native grass on three surface treatments of slate cover and two hand pitted treatments.

Untreated	12.5% slate cover	25% slate cover	50% slate cover	25% hand pitting	25% hand pitting with sod
7.5	8.2	6.9	7.0	8.0	9.1
7.9	7.1	9.0	6.6	8.4	11.0
6.4	8.3	9.1	6.9	8.0	9.7
7.2	8.3	8.1	7.6	9.1	10.3
6.8	7.5	7.2	7.6	9.4	10.4
7.2	8.1	9.3	6.9	8.8	9.6
Ave:					
7.2	7.9	8.3	7.1	8.6	10.0

Differences among treatments were significant at the .01 level. On the basis of least significant difference of 1.06 percent protein at the .01 level of confidence, grass sampled from the 25 percent hand pitting with sods had the highest protein. Samples from the 50 percent slate and 25 percent hand pitting had significantly higher protein contents than those from the untreated range. The grasses from the 12.5 percent slate and 25 percent slate treatments did not have a significantly higher protein level than the grasses from untreated range.

Protein content of native grasses--pitting without sods, pitting with sods and untreated range.

Grass samples were clipped from a pitted area from which the sods had been removed, from a pitted area on which the sods had been left and from an untreated area of range. Protein percentages were determined and compared (Table 2).

Table 2. Percent protein of native grass from untreated range and pitted range with and without sods.

Untreated range	Pitted range sods removed	Pitted range sods left
7.5	7.2	9.5
7.9	7.5	9.7
6.4	7.3	9.1
7.2	8.0	9.8
6.8	7.6	10.2
7.2	7.5	9.0
7.1	7.2	10.1
8.3	9.1	10.3
6.7	8.0	9.1
6.9	8.3	8.7
Ave:		
7.2	7.7	9.5

Analyses of the data showed that protein differences were significant at the .05 level. Protein of the native grass was 1.8 percent higher where sods were left than the protein content of the grass clipped from the pitting from which the sods had been removed. Difference in protein content was 2.3 percent higher for pitting with sods over the untreated area. Grass clipped from pitted range where sods were removed did not have a significantly higher protein content than the grass from the untreated area.

Protein content of native grasses at 3" increments away from pits, sods, and slates.

The protein content of the vegetation immediately adjacent to the sods, pits, and slates were measured (Table 3). The slates (11" x 18" shingles) were included in these measurements because slate cover was one of the first techniques used to effect controlled vegetation removal. The protein content of the grasses decreases with distance from either the inverted sod, the pit, or the slate.

Table 3. Average percent protein for three treatments at four 3 inch increments away from a slate shingle, a pit and a sod.

Distance away from treatment	Slate	Pit	Sod
0-3"	10.0	11.8	12.9
3-6"	9.0	11.3	12.2
6-9"	8.8	10.8	12.7
9-12"	7.5	7.2	7.9

Another comparison of the protein content of the grasses on pitting with sods removed and pitting with the sods left was made. This was done to establish the value of leaving the sods, which come from the pits, in placement to the pit. Two pitting treatments were measured, that of 25 percent hand pitting and machine pitting. The grasses were clipped at three 3" increments away from the sods where they would have been if they had been left. The protein content of the grasses were higher on pitting where the sods were left and higher for each clipped increment (Table 4). The increase in protein for sods left over sods removed, and at each increment for sods left was significant at the .01 and .10 levels respectively.

Table 4. Average protein content of native grasses on hand and machine pittings, with and without sods.

	Sods removed		With sods	
	25% hand pitting	Machine pitting	25% hand pitting	Machine pitting
0-3"	11.8	11.2	12.9	13.8
3-6"	11.5	10.9	12.2	12.8
6-9"	10.8	10.6	12.7	12.2

The comparison of protein content of native grass clipped in the fall of the year.

Clippings were made in the month of September from an untreated area and from an area of pitting and on an area of interseeding. This was done to determine if the higher protein content of the treated areas carries through into the fall. Average protein content for the three areas were:

Untreated -	4.2 percent
Pitting -	4.6 percent
Interseeding -	3.7 percent

Total protein of the grass in the fall drops significantly and there is no difference between treated and untreated areas.

The relationship between clubmoss and the protein content of native grasses with pitting.

A reasonably good agreement between increased nitrogen production under sods, the potential nitrogen from clubmoss, and the increased nitrogen content of the native grasses up to the flowering stage of growth has been found.

Table 5. Increased nitrogen content in pounds per acre of the native grasses for four years from the pitting treatment.

	1961	1962	1964	1965
Untreated	2.9	2.8	4.2	10.3
Pitted	9.7	8.0	18.0	15.7
Lbs. N increase per acre	6.8	5.2	13.8	5.4

Average increase per year - 7.8 pounds of N per acre.

The pounds of potential nitrogen possible from decomposition of clubmoss has been calculated at 6.8 pounds per acre. (Calculated from clubmoss production data and clubmoss protein content, Tables 4 and 5 respectively of 1966 report). The average pounds of nitrogen measured on 10 dates to 6 inches of depth is (Table 8 - 'A' treatment, 1966 report) 7.9 pounds per acre (Table 5). In summary:

Increased nitrogen content of grasses -	7.8 pounds per acre.
Potential nitrogen from clubmoss -	6.8 pounds per acre.
Soil nitrogen to 6" under sods -	7.9 pounds per acre.

The average soil nitrogen content to a 6" depth for 10 dates of sampling in an untreated area was 5.5 pounds per acre. (From Table 8, 1966 report, C treatment). This is a possible 2.4 pounds of N per acre that is available to the grass on any date. For the active four month growing period of April through July, this is 9.6 pounds of N per acre which is more than the average increase in grass nitrogen content per acre.

The relatively small amount of increased nitrogen made available to native grasses with a range renovation technique involving an inverted sod is significantly important in increased quality, and productions of native grasses.

The relationship of soil surface temperature and soil moisture content.

In 1965 and 1966 soil temperatures were measured in sods, under sods, below untreated areas, in pits. This data was reported in the 1966 report, figure 10. Moisture measurements were also taken to establish, if any, the relationship of the soil temperature and the soil moisture, figure 11 a-h of the 1966 report. No relationship between moisture movement and temperature was indicated.

In 1967, water was added and an area was mechanically treated to produce a 50 percent removal of vegetation with sods and pits. Moisture measurements were made at six inch increments to 36 inches and soil surface temperatures were measured. Measurements were made every 3 hours for 48 hour periods. The data was treated to determine if a correlation existed between soil surface temperatures and moisture content to 36" over a 48 hour period. Data was collected on July 14 and August 18. Soil surface temperature does not, it was found, influence soil moisture movement under any of the areas in pitted range or untreated range (Table 6).

Table 6. The correlation coefficients for surface soil temperatures versus soil moisture under 3 surface conditions of treated range and untreated range, for two dates.

	July 14	August 18
Soil temperature vs. moisture under sod	.03	-.13
Soil temperature vs. between pits	-.05	0
Soil temperature vs. in pits	0	-.02
Soil temperature vs. untreated range	-.02	-.04

Soil moisture storage under pitted range.

The area to which moisture was added was also utilized to give further information on moisture storage under pitting treatment.

When water was added on July 14 and moisture measurements made for 48 hour periods to 3 feet, soil moisture storage under treated areas was not found to differ from that under untreated areas. With the exception of spring moisture storage, from early spring run-off, no difference in storage between treated and untreated areas, for any natural precipitation received has always been found to be the case. However, when storage measurements were made on August 18, significant differences were measured (Table 7).

Table 7. Soil moisture storage increase under pitted range over soil moisture storage under untreated range.

	Storage moisture increase over untreated area for 3 foot depth in acre inches.
Under sods	1.38"
Between pits	.77"
Under pits	No increase
Ave. of sod and between pits	1.07"
Full pitted area ave.	1.00"

Areas within the treatment were found to exert different influences upon storage directly below. The surface conditions are ranked according to effectiveness in Table 8.

Table 8. The average moisture content per six increments as measured on August 18 under surface features of pitting and under an untreated area.

Surface conditions	Acre inches
Under sod	1.37"
Between pits	1.17"
Under pits	1.12"
Untreated range	1.02"

Average soil moisture content under sods were significantly higher than 'Between Pits', 'Under Pits', and Untreated Range.

The difference for 'Between Pits' and 'Under Pits' was not significant. The difference for 'Between Pits' and Untreated Range was significant. Difference between 'Under Pits' and Native Range was not significant.

The sampling depths also varied significantly for average soil moisture storage (Table 9).

Table 9. Measured soil moisture storage by depth increment and ranked in order of soil moisture content on August 18.

Soil depth	Moisture content
12-18"	1.57"
6-12"	1.44"
18-24"	1.36"
24-30"	1.01"
0-6"	.91"
30-36"	.77"

Difference between 12-18" depth and all other depths is significant. The 6-12" and 18-24" depths do not differ significantly but are significantly higher than the 24-30", 0-6", and 30-36" depths.

The 24-30" and 0-6" depths do not differ but both differ significantly from the 30-36" depth.

That no differences were found in moisture storage and content at different depths for July 14 for the total profile can be explained by the fact that the vegetation was still physiologically active, and the plant use factor plus surface evaporation masked any difference that may have existed. By August 18th the grasses were dormant, differences could then be effectively measured.

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